10/501279

PCT/GB 2003 / 000072

10 Rec'd PCT/PTO 09 JUL 2004

The Patent Office

INVESTOR IN PEOPLE

REC'D 10 MAR 2003

WIPO PCT

The Patent Office
Concept House
Cardiff Road
Newport
South Wales
NP10 8QQ

**PRIORITY DOCUMENT**
SUBMITTED OR TRANSMITTED IN COMPLIANCE WITH RULE 17.1(a) OR (b)

I, the undersigned, being an officer duly authorised in accordance with Section 74(1) and (4) of the Deregulation & Contracting Out Act 1994, to sign and issue certificates on behalf of the Comptroller-General, hereby certify that annexed hereto is a true copy of the documents as originally filed in connection with the patent application identified therein.

In accordance with the Patents (Companies Re-registration) Rules 1982, if a company named in this certificate and any accompanying documents has re-registered under the Companies Act 1980 with the same name as that with which it was registered immediately before re-registration save for the substitution as, or inclusion as, the last part of the name of the words "public limited company" or their equivalents in Welsh, references to the name of the company in this certificate and any accompanying documents shall be treated as references to the name with which it is so re-registered.

In accordance with the rules, the words "public limited company" may be replaced by p.l.c., plc, P.L.C. or PLC.

Re-registration under the Companies Act does not constitute a new legal entity but merely subjects the company to certain additional company law rules.

Signed Stephen Hordley.

Dated 12 February 2003

BEST AVAILABLE COPY

**Patents Form 1/77**

Patents Act 1977
(Rule 16)

The Patent Office

THE PATENT OFFICE
A
10 JAN 2002
RECEIVED BY FAX

1/77

# Request for grant of a patent

*(See the notes on the back of this form. You can also get an explanatory leaflet from the Patent Office to help you fill in this form)*

**The Patent Office**

Cardiff Road
Newport
South Wales
NP10 8QQ

| | |
|---|---|
| 1. Your reference | WJ/jt |
| 2. Patent application number *(The Patent Office will fill in this part)* | **0200438.0** |
| 3. Full name, address and postcode of the or of each applicant *(underline all surnames)* | Coventry University<br>Priory Street<br>COVENTRY<br>CV1 5FP |
| Patents ADP number *(if you know it)* | 6153480001 |
| If the applicant is a corporate body, give the country/state of its incorporation | GB |
| 4. Title of the invention | STABILISATION OF LIQUID METAL ELECTROLYTE SYSTEMS |
| 5. Name of your agent *(if you have one)* | **i.p.21** Limited |
| "Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)* | Norwich Research Park<br>Colney<br>NORWICH NR4 7UT |
| Patents ADP number *(if you know it)* | 8060758001 |

10JAN02 E686689-1 C69640
P01/7700 0.00-0200438.0

| 6. If you are declaring priority from one or more earlier patent applications, give the country and the date of filing of the or of each of these earlier applications and *(if you know it)* the or each application number | Country | Priority application number *(if you know it)* | Date of filing *(day / month / year)* |
|---|---|---|---|
| | | | |

| 7. If this application is divided or otherwise derived from an earlier UK application, give the number and the filing date of the earlier application | Number of earlier application | Date of filing *(day / month / year)* |
|---|---|---|
| | | |

| | |
|---|---|
| 8. Is a statement of inventorship and of right to grant of a patent required in support of this request? *(Answer 'Yes' if:*<br>*a) any applicant named in part 3 is not an inventor, or*<br>*b) there is an inventor who is not named as an applicant, or*<br>*c) any named applicant is a corporate body.*<br>*See note (d))* | YES |

**Patents Form 1/77**

9. Enter the number of sheets for any of the following items you are filing with this form. Do not count copies of the same document

| | |
|---|---|
| Continuation sheets of this form | |
| Description | 6 |
| Claim(s) | 1 |
| Abstract | - |
| Drawing(s) | 2 |

10. If you are also filing any of the following, state how many against each item.

| | |
|---|---|
| Priority documents | |
| Translations of priority documents | |
| Statement of inventorship and right to grant of a patent *(Patents Form 7/77)* | |
| Request for preliminary examination and search *(Patents Form 9/77)* | |
| Request for substantive examination *(Patents Form 10/77)* | |
| Any other documents *(please specify)* | |

11. I/We request the grant of a patent on the basis of this application.

Signature IP21 Limited Date 8/01/02

12. Name and daytime telephone number of person to contact in the United Kingdom

WILLIAM JONES
01603-457008

**Warning**
*After an application for a patent has been filed, the Comptroller of the Patent Office will consider whether publication or communication of the invention should be prohibited or restricted under Section 22 of the Patents Act 1977. You will be informed if it is necessary to prohibit or restrict your invention in this way. Furthermore, if you live in the United Kingdom, Section 23 of the Patents Act 1977 stops you from applying for a patent abroad without first getting written permission from the Patent Office unless an application has been filed at least 6 weeks beforehand in the United Kingdom for a patent for the same invention and either no direction prohibiting publication or communication has been given, or any such direction has been revoked.*

**Notes**

a) *If you need help to fill in this form or you have any questions, please contact the Patent Office on 08459 500505.*

b) *Write your answers in capital letters using black ink or you may type them.*

c) *If there is not enough space for all the relevant details on any part of this form, please continue on a separate sheet of paper and write "see continuation sheet" in the relevant part(s). Any continuation sheet should be attached to this form.*

d) *If you have answered 'Yes' Patents Form 7/77 will need to be filed.*

e) *Once you have filled in the form you must remember to sign and date it.*

f) *For details of the fee and ways to pay please contact the Patent Office.*

# STABILISATION OF LIQUID METAL ELECTROLYTE SYSTEMS

## Field of the Invention

The invention relates to liquid metal electrolyte systems and is especially, though not exclusively, applicable to improving the efficiency and reducing the operating costs of modern-day aluminium reduction cells.

## Review of the Art currently known to the Applicants

The invention will be exemplified, and will subsequently be described and illustrated in this present specification, with reference to aluminium reduction or smelting.

Modern aluminium production plants consume huge amounts of electricity. Virtually all of them operate by reducing alumina in electrolysis cells or, as they are called, pots. In practise a commercial aluminium smelting plant will consist of several hundred such pots and will operate on a continuous production basis.

There are two remarkable features of this process. First, it has remained virtually unchanged for over a century since it was first successfully developed (and indeed

it is still universally known as the Hall-Héroult process after the two scientists who first independently discovered it). Second, the amount of energy consumed by the process is quite staggering.

It has been estimated that the modern-day production of aluminium consumes about two per cent of all electricity generated worldwide (!) and yet much of this energy is absorbed in overcoming resistive losses in the poorly conductive highly resistive electrolyte layer of each individual smelting cell. The primary electrical driving current can be of low voltage but must be of relatively enormous amperage in order for the process to work, given these drawbacks, and it follows that any modification which enables that current, the electrolyte thickness, or both, to be reduced at all would indeed produce reductions in energy consumption which could truly be described as significant in relation to those needed without the modification today.

Efforts have been made, naturally, to overcome this problem but the main limiting factor is that, if the electrolyte thickness is reduced beyond a certain critical level, instabilities begin to occur at the interface between the liquid electrolyte and the liquid aluminium. These instabilities, which manifest themselves as a sloshing of the liquids within the cell, have been the subject of intensive research for some 20 years or more. In effect, these are interfacial gravity waves, modified by the external magnetic fields which pervade the cell and when a certain stability threshold is exceeded, these waves can grow by absorbing energy from the ambient electric and magnetic fields.

The good news is that the wave period is measured in minutes and its growth rate in hours, and so the problem ought to be susceptible to some controlled solution. The real problem is that once such a wave takes hold, it can disrupt the electrolysis to such an extent that the cell must be withdrawn from operation. In an extreme case, it could destroy the entire cell.

Previously proposed means for trying to eliminate these instabilities include:

- Placing baffles in the aluminium to break up the long-wavelength waves whilst relying on friction to dissipate the short-wavelength components.

- Have a sloping cathode block so that the aluminium continually drains away.

- Destroy the standing waves by placing hydraulic energy absorbers at the edges of the cell.

- Tilt the anode in harmony with the wave so that the electrolyte layer remains almost uniform and thus one eliminates the perturbation in current.

The first of these prior proposals remains simplistically attractive but both it and the second one are limited by the need to find, in practical environments, a material which survives the chemically aggressive environment in a smelting cell. The second option has another difficulty in that thin aluminium layers will not properly wet the cathode and this cannot easily or cheaply be overcome. Whilst the third option is self-explanatory, the most recent research has concentrated on the final one but as far as is known, no practical embodiment has yet emerged.

In summary, despite the length of time the problem has been around, and the importance of modern aluminium production to the progress of industrialised society as a whole in an era when, paradoxically, conservation of energy is becoming more urgent than ever, instability of aluminium reduction cells remains the central and unsolved problem in the industry at large.

## The Inventive Concept

The applicants are proposing a modification of existing current-driven liquid metal electrolyte systems (of which an aluminium reduction cell is the obvious but not limiting example) which starts from a point quite different from any of those outlined above – but which could, we believe, be used in any appropriate combination with some, all, or any of the prior proposals outlined above.

In essence, we impose on such a system an additional, external, magnetic field whose design and operating parameters are so chosen as to enable the electrolyte thickness to be reduced significantly in relation to those needed without the modification. By doing this, we address the very source of the instability, which happens due to the interaction of the currents induced by the interface motion with the external magnetic field.

Based on our understanding of the fundamental mechanism governing the instability, we believe it to be possible that, with appropriately designed coils, a ring current around the cell inducing an automating magnetic field will stabilise the cell to an appreciable if not total extent.

Thus, rather than trying to understand fully all the processes happening inside the cell we effectively suppress the fluctuations by imposing a suitably powerful and time-dependent magnetic field around it. A modern aluminium (or any other metal) reduction cell is a complex and highly optimised device. There are a multitude of supple physical and chemical processes occurring within such a cell and many of them will inevitably interact. A small change in any one parameter could well have quite unexpected consequences and these may or may not be either inter-related or predictable at all. The size alone of the primary driving current makes it almost impractical to try to make relatively small adjustments to any one aspect of cell operation – for example, the "anode-tilt" approach exemplified in the fourth prior proposal outlined previously – with any real guarantee of even partial success.

We by contrast take an overview and we believe that, with appropriate design and with the ability to adjust the controlling parameters (i.e. field amplitude, frequency, and constant background) we are more likely to achieve real suppression of instability in a practical format within the foreseeable future.

Brief Description of the Drawings accompanying this text

The accompanying drawings:

Figure 1 shows diagrammatically an example of a modern Hall-Héroult cell;

Figure 2 presents the electrolysis zone of the cell schematically;

Figure 3 shows graphically the existing and the modified instability levels occurring in respectively an unmodified and a modified cell in accordance with the invention; and

Figure 4 shows, again in schematic form, one possible set-up embodying the invention.

Description of the Proposal in Outline

An example of a modern Hall-Héroult cell is shown in Figure 1.

The current used in the electrolysis enters the electrolyte zone vertically through the anode and is collected by the cathode at the bottom. The thickness of both layers, electrolyte and aluminium, is very small in comparison with the horizontal dimensions. Schematically, the electrolysis zone can be presented as shown in Figure 2.

The major part of the consumed energy is wasted in the form of resistive losses in

the poorly conductive electrolyte, layer 1 in Figure 2. But, when the depth of electrolyte is reduced below some critical level or the current exceeds some critical value, the cell becomes unstable. In other words, the waves at the interface between the two liquids start growing. The increment of the resulting instability is shown in Figure 3 (curve 1).

We propose to apply an external, alternating magnetic field. We believe that the currents induced by this field can be so regulated as to suppress instability. The sketch of a possible set-up is shown in Figure 4. A ring current around the cell induces an alternating magnetic field. The result of simulations for the same cell parameters in this case is presented by curve 2 in Figure 3. One can see that the instability disappears.

The set-up in Figure 4 and the results of calculations in Figure 3 have been present for a circular geometry, which is the most unstable case. We believe, however, that the method will work for any geometry of the cell.

The current scope of the invention is designed in the claims which now follow.

## CLAIMS

1. Modifying a current-driven liquid metal electrolyte system by imposing on the system an additional, external, time-varying and/or alternating magnetic field whose design and operating parameters are so chosen as to counteract any instabilities generated at the liquid-liquid interface within the system and thus allow the electrolyte thickness to be reduced significantly in relation to that needed without modification.

2. The invention of Claim 1 when applied to or embodied in an aluminium reduction cell.

3. The proposal substantially as described herein with reference to and as illustrated in any appropriate combination of the accompanying drawings.

4. The invention of any preceding claim in combination with some, all or any of the prior proposals outlined herein for reducing or eliminating instabilities in a liquid metal electrolyte system, in particular an aluminium reduction cell.

1/2

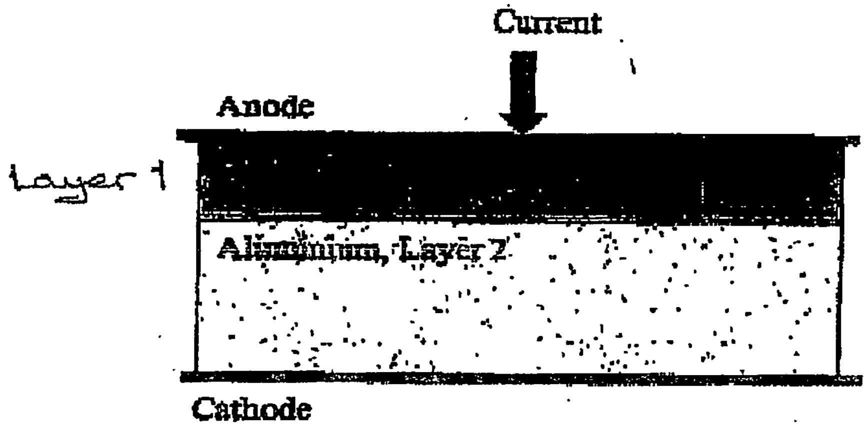
Current
Anode
Layer 1
Aluminium, Layer 2
Cathode

Fig.2

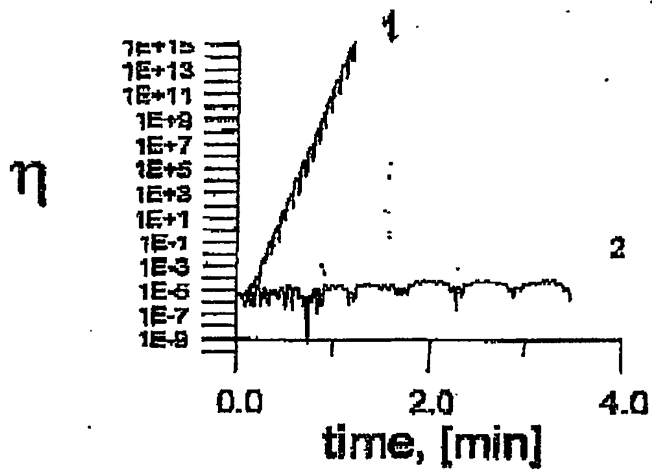
1
2
η
1E+15
1E+13
1E+11
1E+9
1E+7
1E+5
1E+3
1E+1
1E-1
1E-3
1E-5
1E-7
1E-9
0.0
2.0
4.0
time, [min]

Fig. 3

2/2

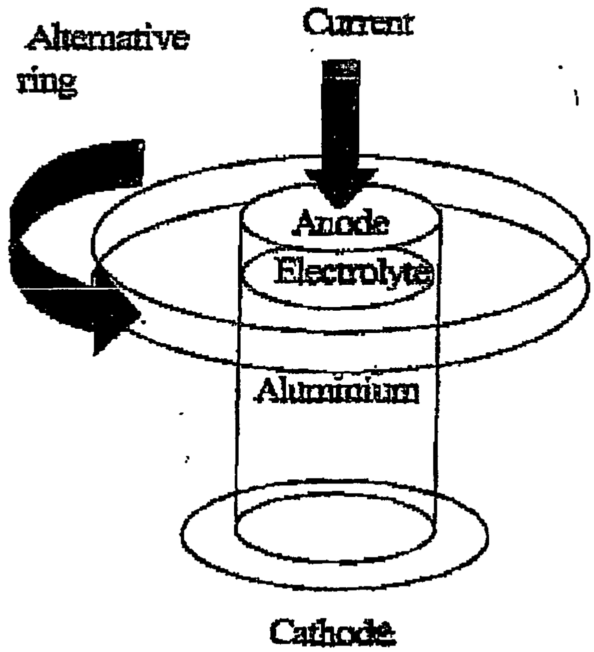
Alternative ring
Current
Anode
Electrolyte
Aluminium
Cathode

Fig.4

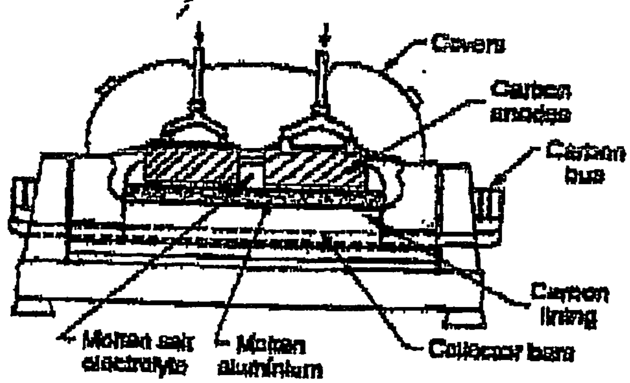
Covers
Carbon anodes
Carbon bus
Carbon lining
Molten salt electrolyte
Molten aluminium
Collector bars

Fig. 1